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CERTIFICATION

I, Birgit Bartell, hereby declare that:

- my name and post office address are as stated below;
- I am knowledgeable in the English and German languages,
- I believe that the attached text is a true and complete translation of German patent application No. 10103927.1, filed with the German Patent Office on January 30, 2001.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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DATA TRANSMISSION SYSTEM

The invention relates to a system for wirefree transmission of data between a base station and at least two mobile stations.

Data transmission systems in which data is interchanged without the use of wires over short distances of only a few meters between a base station and mobile stations are referred to as piconetworks. The frequencies available for data transmission in piconetworks are defined by the ISM frequency bands (Industrial, Scientific and Medical). The ISM frequency bands are reserved for use, based on radio and without licenses, at low transmission powers.

A data transmission from the base station to the mobile stations is referred to as a downlink. The converse case, of data transmission from the mobile stations to the base station, is referred to as an uplink. Time slot methods are normally used for data transmission. In time slot methods, time slots with a specific time duration are assigned to the downlinks and uplinks. The TDMA (time division multiple access) method is frequently used as a multiple access method for time slot methods, and the TDD (time division duplex) method is used as a duplexing method in order to form a bidirectional channel between the base station and the mobile stations.

In previous data transmission systems based on a time slot method, each data block which is intended to be transmitted from the base station to a specific mobile station or from one of the mobile stations to the base station is allocated one time slot. A time slot method such as this is described, by way of example, in the “Bluetooth Specification Version 1.0B”, in Chapter 2, “Physical Channel”, (Internet Address “www.bluetooth.com/developer/specification/Bluetooth_11_Specifications_Book.pdf” and in particular in Chapter 2.3 “Time Slots” (pages 43, 44) there. When successive data burst are transmitted from different stations, it will be possible for the data blocks to overlap in time owing to the asynchronous transmission cycles of the stations. In order to compensate for such an overlap of the data burst originating from different stations, guard time intervals are planned in between the transmission of the individual data bursts. In the following text, the expression data burst means a sequence of one or more data blocks transmitted without any interruption. No data transmission takes place during the guard time intervals.

The Standard defined by the Federal Communications Commission (FCC) for the use of the ISM frequency bands (Internet Address www.fcc.gov/oet/info/rules/part15/) defines a

frequency hopping method (Frequency Hopping Spread Spectrum) and stipulates how may frequency changes must take place within the specific time intervals. The rules relating to this can be found in Section 15.247 of the FCC rules, in particular in Section 15.247 (1) (ii) there. In frequency hopping methods, the transmission frequency is changed once a specific number of data blocks have been transmitted. Every change in the transmission frequency results in the frequency synthesizer requiring time to stabilize the new transmission frequency. The stabilization times must be taken into account in the length of the guard time intervals between the data blocks.

The transmission pauses which are forced to occur by the guard time intervals disadvantageously reduce the data transmission rate. Furthermore, the guard time intervals result in long latency times. The expression latency times in this context means the times which pass from the start of transmission of a data block to a specific station to the reception of the response from this station. These latency times are particularly critical in systems with real-time requirements.

The object of the invention is to provide a data transmission system which allows a high data transmission rate, and in which the latency times are reduced.

The object on which the invention is based is achieved by the features of claims 1, 11 and 21. Advantageous developments and refinements are specified in the dependent claims.

A data transmission system according to the invention comprises a base station and at least two mobile stations, between which data bursts are interchanged by radio, using a time slot method. One major idea of the invention is for the data transmission system to have means for transmission of first data bursts from the base station to mobile stations, with at least some of the first data bursts containing two or more data blocks which are intended for different mobile stations. Furthermore, the data transmission system comprises means for transmission of second data bursts from at last one of the mobile stations to the base station. The second data bursts contain data blocks which are intended for the base station. Guard time intervals, which are produced by suitable means, are provided between successive date bursts.

The means for transmission of the data bursts and for production of the guard time intervals comprise, in particular, the transmitting and receiving devices in the base and mobile stations.

One advantage of the data transmission system according to the invention is that two or more data blocks which are intended for different mobile stations can be transmitted using a single, first data burst. There is thus no need to provide guard time intervals between the data blocks which are intended for the various mobile stations. Since the data blocks which are intended for different mobile stations are transmitted in the first data burst from only one transmitter, namely the base station, the guard time intervals for compensation for asynchronous transmission cycles may be omitted. This results in a high data transmission rate.

A further advantage is that, during the transmission of a first data burst, common information (for example identification information for the piconetwork) may be transmitted only once for two or more data blocks, at the start of the data burst. This makes it possible to make better use of the available bandwidth.

The invention makes it possible to shorten the transmission time for a frame, and to shorten the latency time. The data transmission system according to the invention is thus particularly suitable for use in systems with real-time requirements.

One frame can be defined for repeated, identically structured transmission sequences between the base station and specific mobile stations. For example, one frame may contain a first data burst, which contains data blocks for specific mobile stations and, subsequently, two or more second data bursts, which are transmitted from specific mobile stations to the base station. The data transmission system according to the invention reduces the transmission time for a frame such as this, thus shortening the latency times.

One preferred refinement of the invention provides for the base station and each mobile station to each have a local oscillator. During transmission operation, the frequency of the local oscillator is used to up-mix the baseband signals to the transmission frequency. During reception operation, received signals are down-mixed by the local oscillator frequency to an intermediate frequency band. Local oscillators may be in the form of low-cost electronic components.

The local oscillators are advantageously each included in a phase locked loop (PLL). The phase locked loop controls the frequency of the local oscillator at the frequency of a reference oscillator, to be precise sufficiently accurately that the phase difference is maintained. The phase locked loop cannot only receive the frequency, but can also produce

a desired frequency. The use of a phase locked loop makes it possible to match the receiver-end oscillator frequency to the transmission frequency.

According to one particularly preferred refinement of the invention, first data bursts and groups of second data bursts are transmitted alternately. In this case, it is possible to provide for a first data burst and a subsequent group of that second data bursts to be transmitted at different frequencies, and/or for a group of second data bursts and a subsequent first data burst to be transmitted at different frequencies. Furthermore, the transmission frequency is preferably kept constant during the transmission of a first data burst and during the transmission of a group of second data bursts. This measure means that the local oscillators need to be stabilized to a new transmission frequency only when changing from the first to second data bursts or from the second to first data bursts. The stabilization times make it necessary to provide relatively long guard time intervals. Since the transmission frequency is not changed during the transmission of a group of second data bursts, the guard time intervals between successive second data bursts may, in contrast, be relatively short, since no stabilization process has taken place. This correspondingly increases the data transmission rate.

A guard time interval with the same length as that between a second data burst and a subsequent first data burst is preferably provided between a first data burst and a subsequent second data burst. The FCC rules for the ISM frequency bands require a specific number of frequency changes within specific time intervals. The guard time intervals may be used for changing to a new transmission frequency. It is also possible to provide for the guard time intervals to have the same lengths between successive second data bursts. The purpose of these guard time intervals is protection against time overlapping of second data bursts as a result of any asynchronous transmission cycles of the stations, for example as a result of clock drift. These guard time intervals between successive second data bursts are generally shorter than the guard time intervals between first and second data bursts, since there is no need for the stabilization of the oscillators in this case.

One particularly preferred refinement of the invention is characterized in that the transmitters each produce identification information for the piconetwork at the start of the transmission of each first and of each second data burst. An identification such as this identifies the respective receiver at the start of a transmission of a data burst which is intended for the associated piconetwork. The arrangement according to the invention of the data blocks which are intended for different mobile stations in the single first data burst means that there

is no need to transmit identification information for each data block which is transmitted to a mobile station. This results in a higher data transmission rate.

According to a further advantageous embodiment of the invention, the first data bursts contain two or more data blocks, with one data block being provided for each of the mobile stations. Furthermore, it is advantageous for each of the mobile stations to provide a second data burst in each group of second data bursts. The advantage of this measure is standardization of the transmission sequence. Since each mobile station is addressed in each first data burst and each mobile station is allocated a time slot for transmission of the second data burst in a group of second data bursts, the transmission sequence is clearly structured. The alternative to this would be to check before transmission of each first data burst and each group of second data bursts the mobile stations to which data blocks are intended to be transmitted, and which of the mobile stations require a time slot for data transmission to the base station. In inhomogeneous frame structure such as this would make the latency time worse.

The data transmission system according to the invention can be used, for example, in short-range cordless communication systems. This will be advantageous for cordless telephones with two or more mobile parts. A further application possibility for computer-controlled games systems. In this case, the mobile stations would be the game pads of the individual players. Owing to the short latency time, the use of the data transmission system according to the invention is particularly advantageous for systems which are subject to real-time requirement. In the case of real-time systems, an input which is made at the mobile station end must be transmitted to the fixed station within a defined time interval, which cannot be exceeded. In a corresponding manner, a data block which is produced at the base station end must be transmitted to the mobile station in a time interval which cannot be exceeded. A real-time requirement such as this occurs in computer-controlled games systems.

The frame structure according to the invention is used for radio transmission of data bursts between a base station and at least two mobile stations. The frame structure has first data bursts, which are transmitted from the base station to mobile stations. At least some of the first data bursts contain two or more data blocks which are intended for different mobile stations. Furthermore, the frame structure has second data bursts, which are transmitted from at least one of the mobile stations to the base station. The second data bursts contain data blocks which are intended for the base station. The frame structure according to the invention has guard time intervals between successive data bursts.

The frame structure according to the invention has the advantage that there is no need to provide guard time intervals between the data blocks that are intended for the mobile stations. Since the data blocks which are intended for different mobile stations are transmitted in the first data burst by only one transmitter, namely the base station, there is no need for guard time intervals to compensate for asynchronous transmission cycles. This shortens not only the transmission time for a frame, but also the latency time.

The invention will be explained in the following text by way of example with reference to the drawings, in which:

Fig.1 shows the configuration of a data transmission system which comprises one base station and four mobile stations;

Fig.2 shows an illustration of a frame structure that is used for previous data transmission systems; and

Fig.3 shows an illustration of a frame structure according to the invention.

Fig.1 shows a data transmission system which comprises one base station B and, for example, four mobile stations Mi (i = 1,..., 4). The base station B can transmit data by radio to each of the mobile stations Mi. The mobile stations Mi can likewise transmit data by radio to the base station B. The base station B and the mobile stations Mi each have a local oscillator LO for data transmission for a radio. A data transmission system such as this comprising one base station and N mobile stations is referred to as a piconetwork, and has only a short range.

Fig.2 shows a frame structure which is used, by way of example, in the Bluetooth Standard, in order to interchange data between the base station B (“Master”) and the mobile stations Mi (“Slaves”). Within a frame Ra, data bursts are transmitted as downlinks from the base station B to each of the mobile stations Mi. After receiving a data burst, each of the mobile stations Mi transmits a data burst as an uplink to the base station B, alternating with the downlinks. Each data burst is allocated its own time slot. One time slot TBMa is available for the transmission of a data burst from the base station B to a mobile station Mi. A data burst is transmitted from a mobile station Mi to the base station B during a time slot TBMa. A guard time interval $\Delta T1$, during which no data is transmitted, is provided after each transmission of the data burst.

By way of example, it is possible to provide for the transmission frequency to be varied after each downlink or uplink. Guard time intervals $\Delta T1$ are provided between the transmission of individual data bursts in order to allow the local oscillators LO in the stations to stabilize at the new transmission frequency. If the transmission frequency is not changed between successive data bursts, the guard time intervals $\Delta T1$ are used to compensate for any asynchronous transmission cycles between the stations.

The frame structure which is shown in Fig.2 allows the time Tra that is required for transmission of one frame Ra to be calculated using the following equation:

$$Tra = N \cdot (TBMa + TMBa + 2 \cdot \Delta T1) \quad (1)$$

Equation (1) was based on the assumption of the more general situation, in which the data transmission system N has different mobile stations.

Each of the data bursts that are shown in Fig.2 comprises different groups of data and information. By way of example, in the Bluetooth Standard, identification information CAC (Channel Access Code) for the piconetwork is transmitted at the start of a data burst, followed by the actual data block that is to be transmitted, the header information H, payload data D and a checking bit pattern CRC (Cyclic Redundancy Check) for error identification and correction for the payload data D.

As an exemplary embodiment of the invention, Fig.3 shows the structure of a frame Rb which is transmitted between the base station B and the mobile stations Mi in a data transmission system according to the invention. A data block is in each case transmitted from the base station B to each of the mobile stations Mi as the downlink in a first data burst. The data block which is transmitted from the base station B to the mobile station M1 is annotated "B $\rightarrow$ M1" in Fig.3. The data block which is transmitted from B to M2 is annotated in a corresponding way "B $\rightarrow$ M2" etc. A time slot TBMb is planned for the first data bust. The transmission of the first data burst is followed by a guard time interval $\Delta T2$. During the guard time interval $\Delta T2$, the local oscillators LO are stabilized at a new transmission frequency. After this, successive data bursts are transmitted from each of the mobile stations Mi to the base station B, as uplinks. One time slot TMBb is available for each of these data bursts. The transmission frequency remains constant during the transmission of the uplinks. Guard time intervals $\Delta T3$ are provided between the uplinks in order, for example, to prevent any time overlap between the uplinks owing to asynchronous transmission cycles. The

transmission of the uplinks is once again followed by a guard time interval $\Delta T2$. During this time, the transmission frequency is changed for the transmission of a new frame Rb.

During the transmission of a frame Rb, it is necessary to ensure that the FCC regulations are complied with. This means that the time slots TBMb and TMBb which are provided for the data bursts are sufficiently short to make it possible to change the transmission frequency sufficiently frequently.

As in Fig.2, the data blocks in the exemplary embodiment shown in Fig.3 contain header information H, payload data D and a checking bit pattern CRC. The header information H for the data blocks "B $\rightarrow$ Mi", i = 1,..., 4, represents identification information for the respective mobile stations Mi and, in the Bluetooth Standard by way of example, comprises a 3-bit address for the mobile station Mi. The header information H for the data blocks "Mi $\rightarrow$ B", i = 1,..,4 is the identification information for the base station B, that is to say its address. At the start of a data burst, identification information CAC for the piconetwork is transmitted (in the Bluetooth Standard this is called CAC, the so-called Channel Access Code, which is formed by a 72-bit long sequence).

For the general case with N mobile stations involved, the transmission time TRb for a frame Rb according to the invention is driven by the following equation:

$$TRb = TBMb + N \cdot TMBb + 2 \cdot \Delta T2 + (N - 1) \cdot \Delta T3 \quad (2)$$

In order to make it possible to compare equation (1) with the equation (2), it is assumed that the time slot TBMb for a first data burst according to the exemplary embodiment illustrated in Fig.3 is the same as the N times time slot TBMa. Furthermore, the time slots TBMa, TMBa and TMBb should have the same lengths T. The guard time intervals $\Delta T1$, $\Delta T2$ and $\Delta T3$ are likewise assumed to be identical with the same length ΔT. In consequence, equation (1) becomes:

$$Tra = 2 \cdot N \cdot T + 2 \cdot N \cdot \Delta T \quad (3)$$

With the approximations mentioned above, equation (2) assumes the following form:

$$TRb = 2 \cdot N \cdot T + (N + 1) \cdot \Delta T \quad (4)$$

According to equations (3) and (4), the transmission time TRb for the exemplary embodiment according to the invention is shorter than the transmission time TRa as shown in Fig.2, provided that the data transmission system has at least two mobile stations Mi. This shortening results from the saving of guard time intervals between the data blocks in the first data burst in Fig.3.

The comparison of equations (3) and (4) has not yet taken into account the fact that the transmission of N-1 identification information CAC does not take place in the first data burst according to the invention. This likewise shortens the transmission time TRb compared to TRa.

In summary, a TDMA and a TDD structure with bidirectional channels between the mobile stations Mi and the base station B is created, which to this extent is “asymmetric” with separate unidirectional channels being used for the uplink and a common channel with dynamic allocation of the data rate being used for the downlink.

Patent Claims

1. A data transmission system, which has a base station (B) and at least two mobile stations (Mi), between which data bursts are interchanged by radio using a time slot method, having

- means for transmission of first data bursts from the base station (B) to mobile stations (Mi), with the first data bursts at least in some cases containing several data blocks intended for different mobile stations (Mi),

- means for transmission of second data bursts from at least one of the mobile stations (Mi) to the base station (B) with the second data bursts for the base station (B) containing specific data blocks, and

- means for producing guard time intervals ($\Delta T2$, $\Delta T3$) between successive data bursts.

2. The data transmission system as claimed in claim 1, characterized

- in that the base station (B) and each mobile station (Mi) each have a local oscillator (LO) which, in particular, is connected to a phase locked loop.

3. The data transmission system as claimed in claim 1 or 2, characterized

- in that first data bursts and groups of second data bursts are transmitted alternately.

4. The data transmission system as claimed in claim 3, characterized

- in that a first data burst and a subsequent group of second data bursts are at different transmission frequencies, and/or

- in that one group of second data bursts and a subsequent first data burst are at different transmission frequencies.

5. The data transmission system as claimed in claim 4, characterized

- in that the transmission frequency of a first data burst or of a group of second data bursts is constant during the transmission.

6. The data transmission system as claimed in one of the preceding claims, characterized

- in that the guard time interval ($\Delta T2$) between a first data burst and a subsequent second data burst is equal to the guard time interval ($\Delta T2$) between a second data burst and a subsequent first data burst.

7. The data transmission system as claimed in one of the preceding claims, characterized

- in that the guard time intervals (ΔT3) between successive second data bursts have equal lengths.

8. The data transmission system as claimed in one of the preceding claims, characterized
   - in that the means for transmission of first data bursts have means for producing identification information (CAC) of the piconetwork at the beginning of the transmission of each first data burst, and
   - in that the means for transmission of second data bursts have means for producing identification information (CAC) of the piconetwork at the beginning of each second data burst.

9. The data transmission system as claimed in one of the preceding claims, characterized
   - in that the first data bursts contain several data blocks, with one data block being provided for each of the mobile stations (Mi), and
   - in that a second data burst from each of the mobile stations (Mi) is in each case provided in the group of second data bursts.

10. The data transmission system as claimed in one of the preceding claims, characterized
    - in that the data transmission system can be used
      - in cordless communication systems, or
      - in computer-controlled entertainment systems, in particular in computer-controlled game systems, or
      - in systems with real-time requirements.

11. A frame structure for radio transmission of data bursts between a base station (B) and at least two mobile stations (Mi) having
    - first data bursts which are transmitted from the base station (B) to mobile stations (Mi), with the first data bursts, at least in some cases, containing several data blocks intended for different mobile stations (Mi),
    - second data bursts, which are transmitted from at least one of the mobile stations (Mi) to the base station (B), with the second data bursts containing specific data for the base station (B), and
    - guard time intervals (ΔT2) between successive data bursts.

12. The frame structure as claimed in claim 11, characterized

- in that the base station (B) and each mobile station (Mi) each have a local oscillator (LO) which, in particular, is connected to a phase locked loop.

13. The frame structure as claimed in claim 11 or 12, characterized

- in that first data bursts and groups of second data bursts are transmitted alternately.

14. A frame structure as claimed in claim 13, characterized

- in that a first data burst and a subsequent group of second data bursts are at different transmission frequencies, and/or

- in that one group of second data bursts and a subsequent first data burst are at different transmission frequencies.

15. The frame structure as claimed in claim 14, characterized

- in that the transmission frequency of a first data burst or of a group of second data bursts is constant during the transmission.

16. The frame structure as claimed in one of claims 11 to 15, characterized

- in that the guard time interval ($\Delta T2$) between a first data burst and a subsequent second data burst is equal to the guard time interval ($\Delta T2$) between a second data burst and a subsequent first data burst.

17. The frame structure as claimed in one of claims 11 to 16, characterized

- in that the guard time intervals ($\Delta T3$) between successive second data bursts have equal lengths.

18. The frame structure as claimed in one of claims 11 to 17, characterized

in that the frame structure additionally has an identifying information (CAC) of the piconetwork at the beginning of each first data burst, and

in that the frame structure additionally has an identifying information (CAC) at the beginning of each second data burst.

19. The frame structure as claimed in one of claims 11 to 18, characterized

- in that the first data bursts contain several data blocks, with one data block being provided for each mobile station (Mi), and

- in that a second data burst from each of the mobile stations (Mi) is in each case provided in the group of second data bursts.

20. The frame structure as claimed in one of claims 11 to 19, characterized

- in that the frame structure can be used for data transmission
  - in cordless communication systems, or
  - in computer-controlled entertainment systems, in particular in computer-controlled game systems, or
  - in systems with real-time requirements.

21. A method for radio transmission of data between a base station (B) on the one hand and at least two mobile stations (Mi) on the other hand, which method has the following steps:

(1) transmission of a first data burst from the base station (B) to mobile stations (Mi), which data burst contains several data blocks intended for different mobile stations (Mi),

(2) maintaining a guard time interval ($\Delta T2$); and

(3) transmission of second data bursts from at least one of the mobile stations (Mi) to the base station (B), which data bursts contains specific data blocks for the base station (B).

22. The method as claimed in claim 21, characterized

- in that the base station (B) and each mobile station (Mi) transmit and receive data bursts by means of, in each case, one local oscillator (LO) which is, in particular, connected to a phase locked loop.

23. The method as claimed in claim 21 or 22, characterized

- in that first data bursts and groups of second data bursts are transmitted alternately.

24. The method as claimed in claim 23, characterized

- in that a first data burst and a subsequent group of second data bursts are at different transmission frequencies, and/or

- in that one group of second data bursts and a subsequent first data burst are at different transmission frequencies.

25. The method as claimed in claim 24, characterized

- in that the transmission frequency is kept constant during the transmission of a first data burst or during the transmission of a group of second data bursts.

26. The method as claimed in one of claims 21 to 25, characterized

- in that a guard time interval ($\Delta T2$) is maintained between a first data burst and a subsequent second data burst and has the same length as that between a second data burst and a subsequent first data burst.

27. The method as claimed in one of claims 21 to 26, characterized

- in that guard time intervals ($\Delta T3$) of the same length are maintained between successive second data bursts.

28. The method as claimed in one of claims 21 to 27, characterized

-in that the base station (B) sends identifying information (CAC) of a piconetwork at the beginning of the transmission of a first data burst, and

- in that each mobile station (Mi) sends identifying information (CAC) of a piconetwork at the beginning of the transmission of a second data burst.

29. The method as claimed in one of claims 21 to 28, characterized

- in that the first data bursts contain several data blocks with one data block being provided for each of the mobile stations (Mi), and

- in that a second data burst from each of the mobile stations (Mi) is in each case provided in the group of second data bursts.

30. The method as claimed in one of claims 21 to 29, characterized

- in that the method can be used
  - in cordless communication systems, or
  - in computer-controlled entertainment systems, in particular in computer-controlled games systems, or
  - in systems with real-time requirements.

Abstract

Data transmission system

The data transmission system according to the invention has means for transmission of first data bursts from the base station (B) to mobile stations (Mi), with the first data bursts at least in some cases containing two or more data blocks which are intended for different mobile stations (Mi). The data transmission system furthermore has means for transmission of second data bursts from at least one of the mobile stations (Mi) to the base station (B) and means for production of guard time intervals ($\Delta T2$) between successive data bursts.

(Fig.3)

/rp/bb